THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

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ALUMINIUM ALLOY CASTINGS FOR GE

Table I— Comp

Alloy	Specification	Al	Cu	Si	Mg	Fe
Al-Cu-Si-Zn	B.S. 1490-LM-1-M	Bal.	6·0-8·0	2·0-4·0	0·15 max.	1·0 max.
Al-Zn-Cu	B.S. 1490-LM-3-M	Bal.	2·5-4·5	1·3 max.	0·10 max.	1·0 max.
Al-Si-Cu	B.S. 1490-LM-4-M	Bal.	2·0-4·0	4·0-6·0	0·15 max.	0·8 max.
Al-Mg	B.S. 1490-LM-5-M	Bal.	0·1 max.	0·3 max.	3·0-6·0	0·6 max.
Al-Si (Alpax)	B.S. 1490-LM-6-M	Bal.	0·1 max.	10·0-13·0	0·10 max.	0·6 max.
R.R.50 Ceralumin B	B.S. 1490-LM-7-M B.S. 1490-LM-7-P	Bal.	1·0-2·5	1·5-3·5	0·05-0·20	0·3-1·4
Al-Si-Mg	B.S. 1490-LM-8-W B.S. 1490-LM-8-WP	Bal.	0·1 max.	4·5-6·0	0·2-0·6	0·6 max.
Al-Si (Alpax Beta)	B.S. 1490-LM-9-P B.S. 1490-LM-9-WP	Bal.	0·1 max.	10·0-13·0	0·2-0·6	0·6 max.
Al-Mg	B.S. 1490-LM-10-W	Bal.	0·1 max.	0·35 max.	9·5-11·0	0·35 max.
Al-Cu	B.S. 1490-LM-11-W B.S. 1490-LM-11-WP	Bal.	4·0-5·0	0·25 max.	—	0·25 max.
Al-Cu	B.S. 1490-LM-12-WP	Bal.	9·0-10·5	2·0 max.	0·15-0·35	0·5-1·5
Lo-Ex	B.S. 1490-LM-13-WP B.S. 1490-LM-13-WP (Special)	Bal.	0·5-1·3	11·0-13·0	0·8-1·5	0·8 max.
Y Alloy	B.S. 1490-LM-14-M B.S. 1490-LM-14-WP B.S. 1490-LM-14-WP (Special)	Bal.	3·5-4·5	0·6 max.	1·2-1·7	0·6 max.
R.R.53B Ceralumin C	B.S. 1490-LM-15-WP	Bal.	1·3-3·0	0·6-2·0	0·5-1·7	0·8-1·4
Al-Si-Cu	B.S. 1490-LM-16-W B.S. 1490-LM-16-WP	Bal.	1·0-1·5	4·5-5·5	0·4-0·6	0·6 max.
Birmasil Special	B.S. 1490-LM-17-M	Bal.	0·1 max.	10·0-13·0	0·1 max.	0·6 max.
Al-Si	B.S. 1490-LM-18-M	Bal.	0·1 max.	4·5-6·0	0·1 max.	0·6 max.
Aeral A	B.S. 1490-LM-19-W	Bal.	2·0-4·5	0·7 max.	0·2-1·5	0·8 max.
Al-Si	B.S. 1490-LM-20-M	Bal.	0·4	10·0-13·0	0·15 max.	0·7 max.

GENERAL ENGINEERING PURPOSES (B.S.1490:1949)

Composition

Composition per cent.					
Mn	Ni	Zn	Pb	Sn	Other Elements
0·6 max.	0·5 max.	2·0-4·0	0·3 max.	0·2 max.	Total Mn, Ni, Sn and Pb not to exceed 1·0 per cent.
0·5 max.	0·5 max.	9·0-13·0	0·3 max.	0·2 max.	
0·3-0·7	0·35 max.	0·5 max.	0·1 max.	0·05 max.	Ti 0·2 max. Total Mn and Fe not to exceed 1·3 per cent.
0·3-0·7	0·1 max.	0·1 max.	0·05 max.	0·05 max.	
0·5 max.	0·1 max.	0·1 max.	0·1 max.	0·05 max.	
0·1 max.	0·5-1·7	0·1 max.	0·05 max.	0·05 max.	Ti or Nb 0·05-0·30 singly or in total
0·3-0·7	0·1 max.	0·1 max.	0·1 max.	0·05 max.	
0·3-0·7	0·1 max.	0·1 max.	0·1 max.	0·05 max.	
—	—	—	—	—	Ti 0·2 max.
—	—	—	—	—	Ti or Nb 0·05-0·30 singly or in total
0·6 max.	0·5 max.	0·1 max.	0·1 max.	0·1 max.	Total Mn and Fe not to exceed 1·5 per cent.
0·5 max.	2·0-3·0	0·1 max.	0·1 max.	0·1 max.	
0·6 max.	1·8-2·3	0·1 max.	0·05 max.	0·05 max.	Ti 0·2 max.
0·1 max.	0·5-2·0	0·1 max.	0·05 max.	0·05 max.	Ti or Nb 0·05-0·30 singly or in total
0·5 max.	0·25 max.	0·1 max.	0·05 max.	0·05 max.	
0·5 max.	2·5-3·5	0·1 max.	0·1 max.	0·05 max.	
0·5 max.	0·1 max.	0·1 max.	0·1 max.	0·05 max.	
0·1-0·5	—	0·2 max.	0·05 max.	0·05 max.	Cd 0·5-2·5 Ti 0·05-0·2
0·5 max.	0·1 max.	0·2 max.	0·1 max.	0·05 max.	Ti 0·2 max.

Aluminium Alloy Castings for General Engineering Purposes (B.S.1490:1949) (*continued*)

Table II
Mechanical Properties

Alloy	Specification	Maximum Stress Tons per sq. in. (Min.)		Elongation on 2 in. Per cent. (Min.)	
		Sand Cast	Chill Cast	Sand Cast	Chill Cast
Al-Cu-Si-Zn	B.S. 1490-LM-1-M	8·0	10·0	—	—
Al-Zn-Cu	B.S. 1490-LM-3-M	9·0	—	—	—
Al-Si-Cu	B.S. 1490-LM-4-M	9·0	10·0	2	2
Al-Mg	B.S. 1490-LM-5-M	9·0	11·0	3	5
Al-Si (Alpax)	B.S. 1490-LM-6-M	10·5	12·0	5	7
R.R.50 Ceralumin B	B.S. 1490-LM-7-M B.S. 1490-LM-7-P	9·0 10·0	10·0 12·5	2 2	2 3
Al-Si-Mg	B.S. 1490-LM-8-W B.S. 1490-LM-8-WP	11·0 15·0	15·0 17·0	2·5 —	5 2·5
Al-Si (Alpax Beta)	B.S. 1490-LM-9-P B.S. 1490-LM-9-WP	11·0 15·5	15·0 19·0	1·5 —	2 —
Al-Mg	B.S. 1490-LM-10-W	16·0	18·0	7	12
Al-Cu	B.S. 1490-LM-11-W B.S. 1490-LM-11-WP	14·0 18·0	17·0 20·0	7 4	13 9
Al-Cu	B.S. 1490-LM-12-WP	None specified Brinell Hardness 100-150			
Lo-Ex	B.S. 1490-LM-13-WP B.S. 1490-LM-13-WP (Special)	11·0 9·0	16·0 13·0	— —	— —
Y alloy	B.S. 1490-LM-14-M B.S. 1490-LM-14-WP B.S. 1490-LM-14-WP (Special)	10·0 14·0 12·0	12·0 18·0 15·0	— — —	— — —
R.R.53.B. Ceralumin C	B.S. 1490-LM-15-WP	18·0	21·0	—	—
Al-Si-Cu	B.S. 1490-LM-16-W B.S. 1490-LM-16-WP	11·0 15·0	13·0 17·0	2 —	— —
Birmasil Special	B.S. 1490-LM-17-M	12·0	16·0	2	3
Al-Si	B.S. 1490-LM-18-M	7·5	9·0	3	4
Aeral A	B.S. 1490-LM-19-W	14·0	17·0	3	5
Al-Si	B.S. 1490-LM-20-M	10·5	12·0	3·5	5

Abbreviations: M—as cast. W—solution treated. P—aged. WP—fully heat-treated.

ALLOY STEEL CONSERVATION[1]

IN ORDER to conserve nickel and molybdenum, the Minister of Supply has issued a Direction restricting the use of these elements in certain forms of alloy steel. This Direction (effective June 2nd, 1952) prohibits—

(1) conversion, by steelmakers, of alloy steel into machining bars or forgings (including drop forgings) up to 6-in. ruling section,

and

(2) supply, to steelmakers, of alloy steel for such conversion, unless

either

(*a*) (i) the steel contains no nickel or molybdenum; or

(ii) the steel contains less than certain specified amounts of nickel and of molybdenum, and the bar or forging complies with certain minimum tensile strength and ruling section requirements as shown in Table I,

or

(*b*) the use of a steel richer in nickel or molybdenum has been authorized by an Alloy Steel Assent issued by the Director, Alloy Steel Control, on behalf of the Minister of Supply.

The above restrictions *do not, however, apply*—

(*a*) to alloy steels which are to be converted into products other than machining bars or forgings; *nor*

(*b*) to an alloy steel—in any form whatsoever—which is in one or other of the following specified categories:—

Corrosion-resisting, heat-resisting or creep-resisting steels,
Nitriding steels,
Tool, die, spring, magnet or ball-bearing steels,
Steels to the Ministry of Supply 'DTD' specifications or the 'S' series of specifications of the British Standards for Aircraft Materials and Components published by the British Standards Institution, when such steels are subject to A.I.D. inspection and are used for a specified purpose.

Also, the above restrictions *do not apply* to alloy steels produced solely 'for export' or solely for conversion into a machining bar or forging which is itself solely 'for export' as such.

The Technical Committee of the Steel (Rearmament) Panel has made recommendations, and from time to time may make further recommendations, concerning steels to En specifications which are most suitable for use in complying with the above-mentioned Direction. Details of these recommended steels will be found in Tables II to V.

Table II shows the hardening and tempering steels which can be used without an Assent for given tensile ranges and diameters or ruling sections, and Table III gives chemical compositions of such steels. Any permitted steel can, however, be up-graded, but *must not be* down-graded. The recommended case-hardening steels for specified tensile ranges are given in the two right-hand columns of Table V: steels which they replace are shown in the left-hand columns.

[1] See also *Metal Treatment*, 1952, vol. 19, May, p. 203.

Table I
Hardening and Tempering Alloy Steels

Maximum Content of		Minimum Tensile Strength	Minimum Ruling Section
Nickel %	Molybdenum %	t.s.i.	
1·00	0·25	45	Not limited
1·60	0·20		
1·80	0·35	55 60 65 70	4-in. 2½-in. 1⅛-in. Not limited
2·80	0·60	60 65 75	4-in. 2½-in. 1⅛-in.
4·30	0·30	100	Not limited if air hardened and tempered. 4-in. if heat-treated otherwise.

Carburizing Alloy Steels

Maximum Content of		Minimum Tensile Strength of Ultimate Product when heat-treated as a 1⅛-in. bar t.s.i.
Nickel %	Molybdenum %	
1·00	0·10	45
0·70	0·15	
1·25	0·10	55
1·50	0·15	65
2·00	0·20	75
2·20	0·25	85 (but when heat-treated at test-piece size)

Table IV gives details of the chemical compositions of the new case-hardening steels.

The Ministry of Supply Direction defines an 'alloy steel' as any steel containing, by weight, one or more of the following elements in the percentages stated:—

Chromium	0·40 or more per cent.
Manganese	10·00 „ „ „
Molybdenum	0·10 „ „ „
Nickel	0·40 „ „ „
Tungsten	0·10 „ „ „
Vanadium	0·10 „ „ „

Table II

Restricted Hardening and Tempering Steels for Sizes up to 6-in. (152 mm.) Ruling Section

Tensile Range		Diameter or Ruling Section				
t.s.i.	kg./mm²	in. : up to $\frac{7}{8}$ mm. : up to 22·2	$\frac{7}{8}$ to $1\frac{1}{8}$ 22·2 to 28·6	$1\frac{1}{8}$ to $2\frac{1}{2}$ 28·6 to 63·5	$2\frac{1}{2}$ to 4 63·5 to 101·6	4 to 6 101·6 to 152·5
		En No.	En No.	En No.	En No.	En No.
45–55	70·9-86·6	15 18	15 18	15 18	18 100	100 111
50–60	78·7-94·5	15 18	18	18	100 (*a*) 111	100 (*a*) 111
55–65	86·6-102·4	18 100 111	18 100 111	100 111	110	24
60–70	94·5-110·2	100 111	100 111	100 (*a*) 110	24	25 (*e*) 29 (*e*)
65–75	102·4-118·1	100 110	100 110	24	25 (*e*) 26 (*e*)	26 (*e*)
70–80	110·2-126·0	110 24	110 24	24 (*b*)	25 (*e*) 26 (*e*)	26 (*e*)
75–85	118·1-133·9	24	24	25 (*e*) 26 (*e*)	26 (*e*)	26 (*e*)
80–90	126·0-141·7	24	24	25 (*e*) 26 (*e*)	26 (*e*)	26 (*e*)
100 min.	157·5 min.	24 110 (*c*) 111 (*c*) 30 (*d*, *e*)	24 110 (*c*) 111 (*c*) 30 (*d*, *e*)	25 (*e*) 26 (*e*) 30 (*d*, *e*)	26 (*e*)	30 (*e*)

(*a*) B.S. 970 quotes S properties on En 100 only up to 4 in. and U properties only up to $1\frac{1}{8}$ in.

(*b*) B.S. 970 quotes W properties on En 24 only up to $1\frac{1}{8}$ in.

(*c*) B.S. 970 does not quote 100 t.s.i. properties on En 100 or En 111. To attain 100 t.s.i. a higher carbon content (0·35-0·45 per cent.) is necessary for En 111.

(*d*) En 30 may be used up to $2\frac{1}{2}$-in. for air hardening and tempering only.

(*e*) The molybdenum content of En 25, En 26 and En 29 must not exceed 0·60 per cent., and of En 30B must not exceed 0·30 per cent., without an Alloy Steel Assent.

Table III

Chemical Composition of Steels Listed in Table II

En No.	Type of Steel	Chemical Composition				
		C %	Mn %	Ni %	Cr %	Mo %
En 15	1·5% Mn	0·3-0·4	1·3-1·7	—	—	—
En 18	1% Cr	0·35-0·45	0·6-0·95	—	0·8-1·1	—
En 24	1¼% Ni-Cr-Mo	0·35-0·45	0·45-0·7	1·3-1·8	0·9-1·4	0·2-0·35
En 25	2½% do. (medium-carbon)	0·27-0·35	0·5-0·7	2·3-2·8	0·5-0·8	0·4-0·7
En 26	do. do. (high-carbon)	0·36-0·44	do.	do.	do.	do.
En 29	3% Cr-Mo	0·15-0·35	0·65 max.	0·4 max.	2·5-3·5	0·3-0·7
En 30A	4¼% Ni-Cr	0·26-0·34	0·4-0·6	3·9-4·3	1·1-1·4	—
En 30B	4¼% Ni-Cr-Mo	do.	do.	do.	do.	0·2-0·4
En 100	Low Alloy	0·35-0·45	1·2-1·5	0·5-1·0	0·3-0·6	0·15-0·25
En 110	Low Ni-Cr-Mo	0·35-0·45	0·4-0·8	1·2-1·6	0·9-1·4	0·1-0·2
En 111	Low Ni-Cr	0·3-0·4	0·6-0·9	1·0-1·5	0·45-0·75	—

In all steels Si is 0·10-0·35 per cent.
S „ 0·05 max. „
P „ 0·05 „ „

Table IV
New 'Economy' Case-Hardening Steels

En. No.	Type of Steel	Chemical Composition					Mechanical Properties of Core		
		C %	Mn %	Ni %	Cr %	Mo %	M.S. t.s.i. min.	E% (3·54D) min.	Izod ft.-lb. min.
351	¾% Ni-Cr	0·22 max.	0·5-1·0	0·5-1·0	0·5-1·0	0·1 max.	45 (70·9)	18	25 (8·0)
352	1% Ni-Cr	do.	do.	0·75-1·25	0·75-1·25	do.	55 (86·6)	15	20 (7·0)
353	1¼% Ni-Cr	do.	do.	1·0-1·5	do.	0·08-0·15	65 (102·4)	12	18 (6·5)
354	1¾% Ni-Cr	do.	do.	1·5-2·0	do.	0·1-0·2	75 (118·1)	12	15 (5·8)
355	2% Ni-Cr-Mo	0·20 max.	0·4-0·7	1·8-2·2	1·4-1·8	0·15-0·25	85 (113·9)	12	15 (5·8)
361	'15' Carbon Low-Alloy	0·13-0·17	0·7-1·0	0·4-0·7	0·55-0·8	0·08-0·15	45 (70·9)	18	25 (8·0)
362	'20' Carbon Low-Alloy	0·18-0·23	do.	do.	do.	do.	55 (86·6)	15	15 (5·8)
363	'25' Carbon Low-Alloy	0·22-0·26	do.	do.	do.	do.	65* (102·4)	—	—

* Required only if steel is supplied on the basis of tensile strength.

N.B.—(1) Heat-treatment of the test-bar consists of: (*a*) Blank carburize at 880°-930°C.; (*b*) Refine at 850°-880°C.; (*c*) Harden in oil from 780°-820°C.; (*d*) Temper at not more than 200°C. for En 355 only.

(2) The test bars are of 1⅛-in. dia. (28·6 mm.) except in the case of En 355, when the test bar is machined to test-piece size (except for a grinding allowance, if required) prior to heat-treatment.

(3) Figures in ( ) refer to equivalent kg./mm² for the maximum stress and kg.m/cm² for the corresponding approximate Charpy (Mesnager notch) values.

Table V
Case-Hardening Steels Related to Tensile Properties

Tensile Range		Steels used per B.S. 970/1947		'Economy' Steels as per Table IV	
t.s.i.	kg./mm²	En No.	Type	En No.	Type
45-55	70·9-86·6	33	3% Ni	351	¾% Ni-Cr
		34	2% Ni-Mo (lower-C.)	361	'15' C, Low-Alloy
55-65	86·6-102·4	35	2% Ni-Mo (higher-C.)	352	1% Ni-Cr
		36T	3% Ni-Cr	362	'20' C, Low-Alloy
		325	2% Ni-Cr-Mo (low-Cr)		
65-75	102·4-118·1	36V	3% Ni-Cr	353	1¼% Ni-Cr
		38	5% Ni	363	'25' C, Low-Alloy
75-85	118·1-133·9	—	—	354	1¾% Ni-Cr
85 min.*	133·9 min.	39A	4¼% Ni-Cr	355	2% Ni-Cr-Mo
		39B	4¼% Ni-Cr-Mo	320	2% Ni-Cr-Mo (high-Cr)
		320	2% Ni-Cr-Mo (high-Cr)		

*** Heat-treated as test-piece size.**

ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

NICKEL

Determination of Nickel and Other Metals in Ores

J. AUBRY and G. LAPLACE: 'Determination of Chromium, Nickel, Cobalt and Copper in the Ores of Lorraine.' *Bull. Soc. Chimique de France*, 1951, pp. 204-6.

Calcareous ores of Lorraine were found to contain (g./metric ton) chromium 65-102, nickel 75-100, copper 57-70; siliceous ores assayed chromium 140-160, cobalt 55-58, nickel 100-120, copper 72-94. A method developed for analysis is described. Essential steps in procedure are given in *Chemical Abstracts*, 1952, vol. 46, Jan. 10, p. 58.

Determination of Traces of Nickel

V. T. CHUYKO: 'Concentration Methods for Determining Traces of Nickel. III. Determination of Nickel in Mixtures of Cations of the Third Analytical Group.' *Jnl. Anal. Chemistry, U.S.S.R.*, 1951, vol. 6, pp. 97-9 ; *Brit. Abstracts, C*, 1952, Part 2, Feb., pp. 50-1.

The abstract contains details of a method for estimation of traces of nickel in presence of large amounts of aluminium, chromium, iron, manganese, cobalt and zinc.

Influence of Nickel-Alloy Core Material on Thermionic Emission of Oxide Cathodes

See abstract on p. 130.

Recovery of Nickel from Silver-Refinery Waste Liquors

N. G. BANERJEE and T. BANERJEE: 'Recovery of Nickel and Zinc from Silver Refinery Waste Liquors: Part I, Recovery of Nickel by Electrodeposition.' *Jnl. Scientific and Industrial Research, India*, 1952, vol. 11, Feb., pp. 76-8.

The authors report a study of methods for recovery of nickel from refinery wastes of mints, which contain about 0·45 per cent. each of nickel and zinc. According to the procedure recommended, zinc is precipitated as sulphide, and from the zinc-free liquor (pH 1·12 or 6·2-6·8) nickel is recovered by electrolysis at 3·5 volt, using a current density of 0·8 amp. per sq. dm. A nickel cathode, and stainless-steel or lead anodes are employed. Recovery of nickel is of the order of 68-70 per cent. Nickel remaining in the residual liquor after electrolysis may be recovered as nickel oxide, or the solution may be reused, after concentration, for further electrolysis.

Composition of Raney Nickel Catalysts

G. W. WATT and S. G. PARKER: 'The Composition of W-6 Raney Nickel.' *Jnl. Amer. Chemical Soc.*, 1952, vol. 74, Feb. 20, pp. 1103-4.

In 1950 IPATIEFF and PINES published data on the composition of W-6 Raney nickel, differing markedly from conclusions drawn by ADKINS and BILLICA (see *Nickel Bulletin*, 1951, vol. 24, No. 2, p. 29), and from earlier work by Watt and Parker. The present note reports results of further experiments which confirmed that the alumina content of W-6 Raney nickel is of the order of 1 per cent., rather than 21 per cent. reported by Ipatieff and Pines. Observations which are believed to have led to the conclusion with regard to high alumina content are discussed. It is also pointed out that the type of specific composition proposed by Ipatieff and Pines is unwarranted, since, even with respect to the two major constituents, nickel and aluminium, Raney W-6 nickel catalyst is not rigorously reproducible, but varies over a relatively wide range of composition, due to unavoidable variation in the conditions prevailing during leaching of the nickel-aluminium alloy.

ELECTRODEPOSITION AND OTHER COATING METHODS

Metal Finishing Handbook

W. F. COXON (Editor): 'Industrial Finishing Year Book, 1952.' *Published by Arrow Press, Ltd., Watford, Herts.*, 1952; 447 pp. Issued free to subscribers to *Industrial Finishing*. Price to non-subscribers 12/6d.

It is emphasized in the preface that the material contained in the 1952 edition of this handbook has been carefully revised, modified and amplified, to ensure an all-over presentation of current knowledge and practice. It brings together items of information on various aspects of the finishing industries, incorporating both commercial and technical items of interest.

The subjects covered, in a degree of detail sufficient to be practically useful, is indicated below by a list of the principal sections of the book:—

Part I. Reference and Technical Data

Survey of Protective Coatings: Factors governing selection of finish.

Cleaning and Brightening Media and Technique.

Polishing: Equipment, polishing compositions; hand- and electro-polishing.

Electroplating: Typical solutions and methods used for deposition of various metals; causes and rectification of faults in coatings; analysis of solutions; barrel plating; stripping; methods of test; patents covering proprietary processes, e.g., for bright nickel plating.

Metal Colouring: Treatments for various metals and alloys.

Finishing of Aluminium.

Finishing of Zinc Alloys.

Selection of Paint Finishes.

Finishing of Wood.

Stove Enamelling; Vitreous Enamelling.

Metal Coatings other than Electrodeposited Coatings: galvanizing, spraying, Sherardizing, tinning, aluminizing, chromizing.

Technical Data: Conversion tables; B.S. specifications (believed to be the only complete published list of the many official specifications affecting the finishing industry); metal-surface testing equipment and procedures; general corrosion-resisting characteristics of metals and alloys; temporary corrosion preventives.

II. Buyers' Guide and Trade Directory

British Professional Institutes and Associations connected with the finishing industries; trade names used in the industry; classified list of sources of supply of equipment and materials.

Metal Finishing Guidebook

'Metal Finishing Guidebook-Directory.' 20th Ann. Edn. *Published by Finishing Publications, Inc.*, 1951; 568 pp. Price 2.50 dollars.

The sections of this book give much practical information on layout of metal-finishing plant, mechanical and chemical methods of surface preparation, plating solutions and technique for deposition of various metals and alloys, special plating processes and surface treatments, analysis and control of solutions, and costs. The handbook also contains a classified directory of U.S. suppliers and manufacturers of plating and related equipment, a list of American trade names of products used in connexion with metal-surface treatments, and information on suppliers of the proprietary articles.

Conservation of Nickel in Electroplating

U.S. DEPT. OF COMMERCE, OFFICE OF TECHNICAL SERVICES: 'Nickel Substitution and Conservation in Electroplating Processes.' *Technical Div. Report TAS* 97: undated.

Following a brief introductory statement of the factors responsible for the current shortage of nickel for plating, details are given of U.S. Orders by which restrictions have been placed on the nickel available to the industry. This is followed by discussion of practice which had become standard (before the shortage) with regard to type and thickness of nickel coatings as underlays to chromium. Consideration is then given to underlay materials which may be used as alternatives to the use of coatings other than nickel for outer coatings, and to methods by which economy may be effected in applications for which nickel plating is retained.

The practical recommendations made are supplemented by extensive reference to published literature dealing more fully with the respective aspects of the subject. Mention is made of research projects now under way at various American universities, with a view to developing substitutes for nickel plating. *Bibliography* of 39 items.

Determination of Cyanides in Plating Wastes

E. J. SERFASS and R. B. FREEMAN: 'Analytical Methods for the Determination of Cyanides in Plating Wastes and in Effluents from Treatment Processes.' *Plating*, 1952, vol. 39, Mar., pp. 267-73.

This paper, issued under the auspices of A.E.S. Research Project No. 2, is designed to provide electroplaters with reliable and reasonably simple methods for determination of cyanide in the various types of solution and at the various concentrations which will be encountered in the treatment and disposal of liquid wastes. The two methods recommended (of which full working details are given) have been selected after experimental investigation of eight different procedures referred to in the literature. They are intended to determine total cyanide, i.e., not only the cyanide present as the anion, CN^-, but also that present in various complexes with metals.

The Salt-Spray Test

F. L. LAQUE: 'A Critical Look at Salt-Spray Tests.' *Materials and Methods*, 1952, vol. 35, Feb., pp. 77-81.

This article, prepared at the request of the editor of *Materials and Methods*, contains a highly critical appraisal of the salt-spray test. The discussion is supported by test data indicating the extent of the information obtainable from observation of behaviour in salt-spray, with emphasis on its limitations and the lack of correlation between test results and service performance. The writer's considered opinion is that:-

'A salt-spray test can be made useful for inspecting different lots of the same product once some standard level of performance has been established. This latter is rendered difficult by numerous observations that failure in a salt-spray test is not always followed by failure in service, nor does a good performance in a salt-spray test guarantee satisfactory behaviour in service. For example, the salt-spray test has been used for want of a better test for the inspection of decorative chromium plating on automotive parts. It has not been wholly satisfactory for this purpose, and its use has been the basis of numerous disputes between purchasers and suppliers. Nevertheless, the fact that it continues to be used so extensively in this field must mean that it has a recognized value, probably principally as a means of disclosing gross defects that might escape detection by other means of inspection.

'However, there seems to be ample evidence to question placing major reliance on this test as a tool of research in the development of improvements in such decorative plating. It is the author's opinion that the major weakness of the salt-spray test is its inadequacy as a research method. Where it has been used for such purpose it has delayed progress. It will continue to be a handicap so long as it is substituted for special tests designed to study, individually or in combination, those factors that actually determine the overall quality of products that require improvement.'

A later issue of *Materials and Methods* will have contributions by other experts in the corrosion-testing field who saw the original manuscript, at the writer's request, before publication. Contributions from others interested in the subject will also be welcomed.

NON-FERROUS ALLOYS

Design Stresses for Pressure Vessels of Copper-Nickel Alloys

The following ruling was recently given by the A.S.M.E. Boiler Code Committee on Case Interpretations, and has since been ratified by the Board of the A.S.M.E., see *Mechanical Engineering*, 1952, vol. 74, Mar., p. 249.

'Case No. 1101-1: Interpretation of Paragraphs U 68-70'.

Enquiry: Will unfired pressure vessels fabricated by fusion welding under the requirements of Paragraphs U 68-70 meet the intent of the Code if the base metal is copper-nickel alloy conforming to Specification SB-111 or SB-171 ?

Reply: It is the opinion of the Committee that copper-nickel alloy conforming to Specification SB-111 or SB 171 may be used for the construction of pressure vessels by fusion welding under the general requirements of paragraphs U-68, U-69 and U-70 provided:

(1) The welding requirements of these paragraphs and Section IX of the Code shall apply with the following limitations:—

(*a*) Qualification tests made on a given thickness of material shall apply to thicknesses varying as much as ± 50 per cent. from that thickness. Not more than two thicknesses need be qualified, but they shall cover the minimum and the maximum thicknesses under consideration.

(*b*) The elongation as determined by the free-bend test shall not be less than 30 per cent.

(2) Stress relieving is not required.

(3) The hydrostatic test described in paragraph U-77 shall be conducted at a pressure equal to $1\frac{1}{2}$ times the working pressure. In case the vessel is to be operated at temperatures exceeding 150°F. (65°C.) the hydrostatic test pressure shall be based on the maximum allowable pressure to be stamped on the vessel, increased by the ratio of the allowable stress at 150°F. (65°C.), and the corresponding allowable stress as given in Table I of this Case, interpolated, if necessary, for the maximum working temperatures to be stamped on the vessel.

(4) The design rules of the Code shall be applied using the allowable working stresses contained in Table I of this Case multiplied by:—

(*a*) For paragraph U-68 construction 90 per cent. joint efficiency.

(*b*) For paragraph U-69 construction 80 per cent. joint efficiency.

(*c*) For paragraph U-70 construction the joint efficiency shall be computed by dividing the SE values given in paragraphs U-70 (*a*) and U-70 (*b*) by 11,000.

(5) In view of the fact that this material is not one of those which suffer loss of impact resistance at low temperatures, the requirements of paragraphs U-140, U-141 and U-142 shall not apply.'

Influence of Nickel-Alloy Core Material on Thermionic Emission of Oxide Cathodes

H. A. POEHLER: 'The Influence of the Core Material on the Thermionic Emission of Oxide Cathodes.' *Proc. Inst. Radio Engineers*, 1952, vol. 40, Feb., pp. 190-6.

The effect of the core material, on the thermionic emission of oxide cathodes, was discounted in early

Maximum Allowable Design Stresses for Copper-Nickel Alloys, p.s.i.

Alloy Material:	Copper-Nickel 70-30		Copper-Nickel 80-20	Copper-Nickel 90-10
Specification No.:	SB-111 Seamless Condenser Tubes Annealed	SB-171 Tube Plates Annealed	SB-111 Seamless Condenser Tubes Annealed	SB-111 Seamless Condenser Tubes Annealed
For Metal Temperatures not exceeding Sub-zero to—				
150°F.	13,300	12,500	12,000	10,000
250°F.	12,700	12,500	11,300	9,500
300°F.	12,300	12,200	11,000	9,300
350°F.	12,000	12,000	10,700	9,000
400°F.	11,700	11,700	10,300	8,700
450°F.	11,300	11,300	10,000	8,300
500°F.	11,000	11,000	9,500	7,500
550°F.	10,500	10,500	9,000	6,700
600°F.	10,000	10,000	8,500	6,000
650°F.	9,500	9,500	8,000	—
700°F.	9,000	9,000	7,500	—

work by DEINNINGER (1908), but the subject was again considered in 1930, and in 1935 BENJAMIN made a major contribution to it: his work and conclusions are, however, adversely criticized by the present author. Since 1939 the problem of the influence of core material has received increasing attention: reference is made to the major literature.

A detailed account is given of the processing technique employed for the tubes used in the present investigation and of the procedure adopted for measurement of emission. The core materials used were binary nickel-base alloys containing, respectively, 3·5 per cent. tungsten, 0·38 per cent. magnesium, 4·0 per cent. aluminium, or 4·8 per cent. manganese: electrolytic nickel cores were used as controls.

The data obtained from the experiments indicate that the core material exerts a clearly marked influence on thermionic emission and that the effects found are in conformity with published theories. The author discusses his observations in relation to conclusions drawn by other investigators, to whose work reference is made in an extensive *bibliography*.

Diffusion in Nickel-Zinc Alloys

W. KÖSTER and J. RAFFELSIEPER: 'Magnetic Investigation of Diffusion Occurring on Sintering of a Nickel-Zinc Alloy.' *Zeitsch. für Metallkunde*, 1952, vol. 43, Feb., pp. 37-9.

Compacts were prepared from carbonyl-nickel and 50-50 nickel-zinc alloy powders, mixed in proportion to give a zinc content of 9 per cent. in the compact. Sintering was carried out at temperatures in the range 600°-1000°C. and the progress of diffusion was observed by means of magnetic measurements. Complete homogeneity was obtained after 12 hours at 1000°C.: at lower temperatures much longer times are required. The calculated activation energy of the diffusion process is 28,000 cal./mol.

Nickel-Gallium Alloys

E. HELLNER: 'The Nickel-Gallium System.' *Zeitsch. für Metallkunde*, 1950, vol. 41, Dec., pp. 480-4.

A detailed report of examination by thermal, microscopical and X-ray methods. A complete equilibrium diagram is presented. For comprehensive abstract of observations made see *Metallurgical Abstracts*, 1952, vol. 19, Feb., pp. 442-3.

Influence of Nickel on Corrosion-Resistance of Aluminium and Aluminium Alloys

M. WHITAKER: 'A Review of Information on the Effect of Impurities on the Corrosion-Resistance of Aluminium.' (Communication from the British Non-Ferrous Metals Research Association.) *Metal Industry*, 1952, vol. 80, Mar. 7, 14, 21 and 28, pp. 183-6, 207-12, 227-30, 247-51; Apr. 4, 11, 18 and 25, pp. 263-6, 288-9, 303-5, 313, 331-2; May 2 and 9, pp. 346-50 and 387-8.

A comprehensive review of the effects of impurities and minor constituents, based mainly on published literature. Information published up to the end of 1951 is covered. Part I is concerned with matters of a general nature, affecting all the aluminium-base materials; Part II deals solely with pure aluminium; Part III contains information relating to the five main groups of wrought aluminium alloy; Part IV covers the principal casting alloys.

The review is essentially a reference work: mode of compilation is directed to this end. In almost all cases the original papers from which the information is taken have been consulted, and lengthy abstracts are given, including details of method of testing, composition and condition of the alloys, and other particulars essential for correct assessment of the results reported.

The supporting *bibliography* contains 175 items.

NICKEL-IRON ALLOYS

Diffusion of Hydrogen in Iron-Nickel Alloys

P. L. CHANG and W. D. G. BENNETT: 'Diffusion of Hydrogen in Iron and Iron Alloys at Elevated Temperatures.' *Jnl. Iron and Steel Inst.*, 1952, vol. 170, Mar., pp. 205-13.

Report of investigation carried out under the aegis of the Andrew Carnegie Research Fund. The effects of chromium, nickel and molybdenum, on the rate of permeation of hydrogen in iron were investigated, using ingot iron; iron-chromium alloys containing 1·38, 2·51 and 4·25 per cent. chromium; iron-nickel alloys containing 0·94, 1·87 and 4·36 per cent. nickel, and iron-molybdenum alloys containing 0·98, 2·36 and 10·36 per cent. molybdenum. Apparatus used, and diffusion specimen, are described. Measurements of permeation rates at various temperatures, both on heating and on cooling, showed that chromium has little effect on permeation in the γ range, but greatly reduces rate of permeation in the α range. Nickel and molybdenum have but little effect.

The permeation equation was re-examined, and a general equation, based on experimental evidence, is proposed.

Properties of Nickel Ferrites

G. A. SMOLENSKII: 'Ferrites of Bivalent Metals.' *Doklady Akad. Nauk S.S.S.R.*, 1951, vol. 78, pp. 921-4; *Chemical Abstracts*, 1952, vol. 46, Jan. 10, p. 52.

Study of the Curie temperature and saturation magnetostriction characteristics of ferromagnetic ferrites of nickel, copper, manganese and magnesium and a non-ferromagnetic zinc-cadmium ferrite. The abstract gives a comprehensive summary of the results.

Torque Curves and Other Properties of Nickel-containing Permanent-Magnet Alloys

K. HOSELITZ and M. MCCAIG: 'Torque Curves and other Properties of Permanent Magnet Alloys.' *Proc. Physical Soc., Sect. B*, 1952, vol. 65, Mar. 1, pp. 229-35.

Torque measurements on columnar Alcomax III alloys were reported by the authors in 1951 (*ibid.*, vol. 64, pp. 549-59; *Nickel Bulletin*, 1951, vol. 24, No. 8, p. 176). The present paper is also mainly concerned with Alcomax III, but in addition records some

data on Alnico, Hycomax, Ticonal and Alcomax IV. Torque curves were obtained after a new series of heat-treatments, the influence of the magnitude of the field applied during cooling was investigated, and measurements were made on samples having random crystals. The authors describe a method of deriving three independent constants of crystal anisotropy without using single crystals.

Processing of Alnico Components

J. H. STARK: 'Low-Cost Processing of Alnico Rotors and Stators.' *Electrical Manufacturing*, 1951, vol. 48, Nov., pp. 125-7, 248, 250, 252, 254.

The article comprises a series of practical recommendations on methods of design and processing by which Alnico magnet rotor and stator castings may be handled with minimum cost, to give optimum results in their many and varied applications. Problems arising in magnetization are also discussed.

CAST IRON

Effect of Nickel and Other Alloy Elements on Heat-Treatment of Cast Iron

M. M. HALLETT: 'The Effect of Alloy Elements on the Heat-Treatment of Grey Cast Iron.' *Alloy Metals Rev.*, 1952, vol. 8, Mar., pp. 2-8.

The publication of the report of Technical Sub-Committee 31 of the Institute of British Foundrymen, on Heat-Treatment of Cast Iron, has focused attention on improvement of properties which may be obtained by heat-treatment, and on factors influencing the results producible. (For summary of report see *Nickel Bulletin*, 1951, vol. 24, No. 7, p. 152). The present article reviews the effects produced by the various alloy elements used in grey cast iron, discussing the subject in relation to their influence in annealing and in hardening treatments. A review is made of the major literature, supported by a *bibliography* of 30 items. The information available is summarized by the author as follows:—

'*Nickel* decreases the stability of iron carbide, reducing the annealing time needed for decomposition of massive iron carbide by about one half for each 1 per cent. nickel added. On the other hand, it retards the breakdown of pearlite to form ferrite and graphite. Nickel promotes deep hardening on oil quenching, by retarding the decomposition of austenite at all sub-critical temperatures, a 2 per cent. addition sufficing to confer satisfactory hardenability in practice.

'*Chromium* powerfully increases the stability of iron carbide, so that irons with much more than 0·5 per cent. chromium are extremely difficult to anneal at normal temperatures. It is also much the most potent common element in preventing breakdown of pearlite. Chromium probably promotes hardenability when it is present in solid solution in the iron, but not when present in massive carbides.

'*Molybdenum* combines some of the characteristics of both nickel and chromium. Although in the vast majority of cases it is added to cast iron for its effect in increasing the strength in the as-cast condition, the combination of characteristics just mentioned makes its use advantageous in castings which are to be heat-treated.

'The action of molybdenum in stabilizing carbide is so mild that it is barely noticeable when present in amounts less than 1 per cent. It retards both the breakdown of pearlite and ferrite and the transformation of austenite to pearlite to about the same degree as nickel, but is less effective in the transformation of austenite at intermediate temperatures. This feature, coupled with its natural strengthening influence, makes it particularly valuable in the acicular irons.

'The evidence on *combined additions of nickel, chromium and molybdenum* is not sufficient to determine whether the total effect is greater than the additive effect of the individual elements, but it has been shown that irons with a combined addition of nickel, chromium and molybdenum harden effectively in heavy sections.

'Data on the remaining elements are almost entirely lacking. *Copper* up to 1·5 per cent. has no marked effect on stability of pearlite, while *vanadium* in small amounts helps to stabilize pearlite and introduces some precipitation of a vanadium carbide during tempering operations.'

Production of Nodular Graphite in Cast Iron

A. KRYNITSKY and H. STERN: 'Experimental Production of Nodular Graphite in Cast Iron.' *Foundry*, 1952, vol. 80, Mar., pp. 106-11, 243-6; Apr., pp. 98-9, 241, 243-4, 246-7.

The authors describe a study of the effects of magnesium, magnesia, magnesite, iron sulphide, calcium, nickel-chromium-molybdenum, and boron, on the graphite structure of several types of cast iron. Effects of variations in type of crucible, inoculating technique, and cooling rate, were also investigated. A theory based on the results obtained in this research and on other data is proposed. Briefly, it suggests that spheroidal-graphite is formed during solidification of the melt, and that graphite particles or aggregates are the result of the decomposition of carbide after solidification.

Spheroidal-Graphite Cast Iron: Current Stage of Development

W. W. BRAIDWOOD: 'Spheroidal-Graphite Cast Iron Up-to-Date.' *Foundry Trade Journal.*, 1952, vol. 92, Apr. 3, pp. 361-6; disc., *ibid.*, Apr. 10, pp. 393-4. *Reprinted as Pubn. 604** by The Mond Nickel Co., Ltd.

This paper surveys the progress of spheroidal-graphite cast iron development, assesses the position now reached, and attempts to forecast its future. The disadvantages of the term 'nodular' are discussed, and the designations 'spheroidal-graphite', for the graphite form, and 'spheroidal-graphite cast iron' for the product, are recommended.

In order to correct certain misapprehensions which have been current with regard to the origin of the invention, the author gives a succinct review of the simultaneous development of the cerium process (by the British Cast Iron Research Association) and the

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magnesium process (by The International Nickel Company and The Mond Nickel Company). The review includes a survey of the patent position to date.

Reference is made to the many purposes for which spheroidal-graphite cast iron is already being used on a commercial scale: typical castings, varying widely in size and weight, are illustrated. In spite of current difficulties with regard to raw materials supply, and other problems of a temporary nature, there is every indication that output of spheroidal-graphite cast iron will steadily increase, and that the material will occupy an increasingly important place in the engineering industries.

Spheroidal-Graphite Cast Iron Troughs for Conveying Molten Aluminium

'Ductile Iron Beats Gray Iron 6 to 1.' *Nickel Topics*, 1952, vol. 5, No. 2, pp. 1, 3.

This note reports successful use of spheroidal-graphite cast iron for pouring troughs conveying molten aluminium (in the plant of Aluminum Company of America) from the holding ladle to the multiple casting unit. Prior to each pouring period the trough is pre-heated by gas, and the pouring temperature varies from 675° to 760°, averaging about 700°C. Grey-iron troughs previously used for this purpose had regularly failed by progressive cracking through the flanges and up the length of the spout, and warping of the flanges: average life for such troughs was only three months. Two troughs in spheroidal-graphite cast iron have now been in 24-hour service, five days a week, for more than 18 months, having carried during that period more than 27 million pounds of aluminium. Recent inspection showed them to be still free from warpage, cracking and erosion, giving promise of a further long period of service.

Ni-Resist in Caustic Manufacture

See abstract on p. 138.

CONSTRUCTIONAL STEELS

Specification for High-Tensile Low-Nickel Alloy Steel

The following specification was issued on 15/2/52 by the Society of Automotive Engineers.

A.M.E. 6427: Low-Alloy Steel

Composition Limits	%
Carbon	0·28–0·33
Manganese	0·80–1·00
Silicon	0·20–0·35
Phosphorus	0·040 max.
Sulphur	0·040 max.
Chromium	0·75–0·95
Nickel	1·65–2·00
Molybdenum	0·35–0·50
Vanadium	0·05–0·10

For bars, forgings and forging stock, primarily for parts requiring high tensile strength and good ductility, with relatively high impact strength and hardness.

Diffusion of Hydrogen in Iron-Nickel Alloys

See abstract on p. 131.

Effect of Structure on Machinability of Nickel-Alloy Steels

N. ZLATIN and L. NOWIKOWSKI: 'Effect of Structure on Machinability Demonstrated.'* *Reprint from Iron Age*, 1951, vol. 168, Aug. 2, pp. 95-8.

Issued by International Nickel Co., Inc., 1952; 4 pp.

For abstract see *Nickel Bulletin*, 1951, vol. 24, No. 10, p. 203.

Determination of Chromium in Alloy Steels

BRIT. IRON AND STEEL RESEARCH ASSOCN.: 'Absorptiometric Determination of Chromium in Iron and Steel.' *Jnl. Iron and Steel Inst.*, 1952, vol. 170, Mar., pp. 268-70.

The paper describes a method developed by the B.I.S.R.A. Methods of Analysis Committee. Suitable conditions were worked out for use of the diphenylcarbazide-chromate reaction for determination of chromium in presence of iron and of most of the other elements occurring in alloy steels. Full details of procedure are given and typical results obtained on various steels are tabulated. The method is recommended as suitable for estimation of low chromium contents (less than 0·3 per cent.). Brief consideration is given to the limitations of other methods.

HEAT- AND CORROSION-RESISTING ALLOYS

Influence of Processing Variables on Creep-Resistance of High-Temperature Alloys

X. WACHÉ: 'Factors Affecting Creep Resistance of Austenitic Alloys having Strength at High Temperature.' *Métaux*, 1952, vol. 27, Feb., pp. 56-68.

The object of this paper is to demonstrate the decisive influence, on creep resistance, of the processing history (both thermal and mechanical) of high-temperature alloys. The significance of such factors is emphasized in relation to their effect on the nature of the precipitated phase present in alloys susceptible to structural hardening by quenching and tempering treatments. This aspect of high-temperature metallurgy is discussed in particular relation to work done in the Imphy laboratories of Société Anonyme de Commentry Fourchambault et Decazeville, on (1) 36-11 per cent. nickel-chromium-iron alloys in which carbides are the hardening medium, and (2) 42 per cent. nickel-iron alloys rendered susceptible to precipitation hardening by additions of titanium and aluminium. The effects of varying cycles of treatment on structure are demonstrated with particular reference to the nature and distribution of the hardening phases, and the structural conditions produced by various treatments are correlated with data on creep-resistance.

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X-Ray Study of Creep in Nickel-containing Materials

W. EPPRECHT: 'X-Ray Structural Studies on Creep of Steel.' *Schweizer Archiv für angewandte Wissenschaft und Technik*, 1952, vol. 18, No. 1, pp. 10-21.

This paper gives an account of work in the laboratories of Gebrüder Sulzer, A.G.: the research reported was supplementary to that carried out by SIEGFRIED (see *Technische Rundschau Sulzer*, 1948, No. 4, pp. 21-35, and *Jnl. Iron and Steel Inst.*, 1947, vol. 156, pp. 189-207).

The materials used for the main tests in the present investigation were of the compositions shown in the table below.

Data are presented on structural changes occurring in these materials at temperatures of 570° to 750°C., under various loads.

Fe	Mn	Ni	Cr	Co	W	Mo	Nb+Ta	V	Al	Ti	Si	Cu	C
%	%	%	%	%	%	%	%	%	%	%	%	%	%
1·3	0·5	74·08	20·5	—	—	—	0·06	0·32	1	2	0·58	tr.	0·09
ca. 70	—	8	18	—	—	—	—	—	—	—	—	—	—
ca. 54	1·02	14·3	13·9	10·0	3·14	2·0	2·3	0·2	—	—	1·4	—	0·47

S.A.E. (A.M.S.) Specifications for Heat- and Corrosion-resisting Alloys

The following are among new and revised specifications recently issued by the Society of Automotive Engineers in the Aeronautical Materials series.

A.M.S. 5537 (15/2/52): Alloy Sheet, Corrosion and Heat Resistant.

Composition Limits	%
Carbon	0·05–0·15
Manganese	1·00–2·00
Silicon	1·00 max.
Phosphorus	0·040 max.
Sulphur	0·030 max.
Chromium	19·00–21·00
Nickel	9·00–11·00
Tungsten	14·00–16·00
Iron	3·00 max.
Cobalt	Remainder

The material is for use primarily in parts such as burner liners, exhaust cone assemblies, nozzle diaphragm vanes, and other parts requiring high strength up to approximately 1500°F. (815°C.) and oxidation-resistance up to 2000°F. (1093°C.). Material for use as bare wire filler material, for welding this alloy, is covered by S.A.E. (A.M.S.) 5796 (15/2/52). Composition limits are as in 5537.

A.M.S. 5577 (15/2/52): Steel Tubing, Welded, Corrosion and Heat Resistant.

Composition Limits	%
Carbon	0·08 max.
Manganese	2·00 max.
Silicon	0·75 max.
Phosphorus	0·040 max.
Sulphur	0·030 max.
Chromium	24·00–26·00
Nickel	19·00–22·00
Molybdenum	0·50 max.
Copper	0·50 max.

To be used primarily for parts and assemblies requiring both corrosion- and heat-resistance, especially welded components; also for parts and assemblies requiring oxidation-resistance up to approximately 2000°F. (1093°C.), but useful at that temperature only when stresses are low.

Emissivity of Nickel, Nickel-Chromium Alloys and Stainless Steel

A. H. SULLY, E. A. BRANDES and R. B. WATERHOUSE: 'Some Measurements of the Total Emissivity of Metals and Pure Refractory Oxides and the Variation of Emissivity with Temperature.' *Brit. Jnl. Applied Physics*, 1952, vol. 3, Mar., pp. 97-101.

The measurements described in this paper were made in connexion with an investigation of the possibility of reducing radiant heat transfer in engines, particularly gas flame-tube systems, by applying to metal parts coatings having a low thermal emissivity. Measurements were made over the range 300°-800°C., on the following metallic materials: Nimonic 75 (nickel-chromium-base alloy), nickel, and 18-8 chromium-nickel steel. In order to determine the effect of surface condition on emissivity, each of these materials, initially shot-blasted or buffed, was tested in the unoxidized condition, and after oxidizing at various temperatures. In the case of the Nimonic alloy and the stainless steel as-rolled surfaces also were tested, in the unoxidized and oxidized conditions.

Results of the emissivity measurements, which are graphically recorded, show that roughening of the surface produced by shot-blasting increased the total emissivity of the polished metal surfaces in the unoxidized condition by a factor varying from 2 (18-8 steel) to 5 (pure nickel). The difference was somewhat reduced after oxidation at 600°C., and was very much less noticeable after oxidation at 900°C., a change which was confirmed on Nimonic 75 oxidized at 1200°C. The emissivity of the as-rolled surface of the Nimonic alloy was found to be very similar to that of the polished surface, apart from rapid oxidation which occurred when the as-rolled material was heated above 650°C. Such oxidation also occurred in the polished specimen, but oxidation on the polished surface proceeded at a lower rate. In the case of the 18-8 steel the as-rolled material showed higher emissivity after oxidation at 600°C. than the polished or shot-blasted surface, an effect which the authors consider to be possibly attributable to inhomogeneity of the surface brought about during the rolling process. Polished and shot-blasted specimens of nickel showed almost identical emissivities after oxidation

at 900°C., but oxidation at 600°C. produced an unexpected effect, in that the roughened surface so treated showed emissivity higher than that of the same surface after oxidation at 900°C. It is suggested that this observation could be explained by the fact that the film of oxide on the polished specimen was much thinner than the film on the shot-blasted surface, and therefore more transparent to radiation from the underlying metal. The shot-blasted surface thus showed the emissivity characteristics of the oxide only. (The influence of coating thickness on emissivity is discussed in some detail in this paper.) The authors point out that previous investigators have reported that nickel oxide shows a lightening in colour after prolonged heating at temperatures of 800°C., and from observations on oxidized nickel held for long periods at 600° and 900°C. it appears that there is an attendant decrease in emissivity at the higher temperature.

Determinations of emissivity of refractory substances covered the oxides ceria, zirconia, thoria, magnesia, alumina and fused silica. Effect of particle size was studied, and it was concluded that some effects encountered were incidental in the particular method of test used, but that true total emissivity of oxides is independent of particle size and would be that of a large single crystal of the substance.

Additional experiments were made to ascertain the accuracy of a statement made some years ago that Lambert's cosine is not obeyed by certain materials, notably polished metals, when the radiation emitted by them at elevated temperatures is observed obliquely to the surface. Determinations of variation of emissivity with angle of emission showed that there is marked deviation from the Lambert cosine law with polished platinum, but that the law is obeyed in Nimonic 75, oxidized nickel, and pure alumina.

Design Stresses for Pressure Vessels of Copper-Nickel Alloys

See abstract on p. 130.

Transformations Producible by Thermal and Mechanical Treatment in Austenitic Steels

P. BASTIEN and J. DEDIEU: 'Magnetic Studies of Martensitic Transformations produced by Cold Working or by Thermal Treatment in Steels containing 18 per cent. Chromium and 4 to 12 per cent. Nickel.' *Comptes Rendus*, 1952, vol. 234, Jan. 14, pp. 334-6.

Gamma-to-alpha transformation was studied in steels of the composition indicated, (1) cold worked to 15, 33·1, 41·4, 59 and 77 per cent. reduction, or (2) drastically quenched in various media. The results lead to the conclusion that it is impossible by thermal methods alone to produce more than 15 per cent. of alpha phase, even in the region of absolute zero, in a low-carbon 18-8 steel, and that this conclusion applies in even more pronounced degree to steels of higher nickel content which, under given quenching conditions, show even smaller amounts of alpha phase. Cold-working, however, if sufficiently drastic, can effect almost complete γ-α transformation in the steels studied.

Production of Titanium-Stabilized Nickel-Chromium Steels

F. ST. VINCENT and R. W. REBHOLZ: 'Efficient Utilization of Titanium Alloys in Stainless Steel Production.' *Jnl. of Metals*, 1952, vol. 4, Mar., pp. 245-6.

The necessity for conservation of niobium has recently led to increased production of titanium-stabilized stainless steels, and much attention is being directed to the efficient use of ferrotitanium alloys. Due to the ability of titanium to form stable oxides and nitrides it has been necessary, in order to ensure reasonable recoveries, to adopt modified furnace procedures, the main features of which are discussed here.

Radiographic Determination of Distribution of Lead in Nickel-Chromium Steel

L. G. ERWALL, A. FRANZEN and M. HILLERT: 'Autoradiographic Investigation of Distribution of Lead in 18-8 Steel.' *Jernkontorets Annaler*, 1951, vol. 135, No. 6, pp. 219-28.

In connexion with difficulties arising in forging and rolling of stainless steels contaminated with lead, a study was made of a steel containing 0·004 per cent. lead. The lead isotope ThB (Pb^{212}) was used as indicator. The autoradiographs were taken on a stripping emulsion (Kodak Autoradiographic Plate) and were compared with the etched surface of the steel at various magnifications. The radioactive lead was found to be situated in the parts of the steel which solidified last, i.e., between the dendrites. It was not uniformly distributed in these parts, but occurred to a large extent grouped in isolated aggregates of a size of approximately 1μ.

Machining of Stainless Steels

E. VON HAMBACH: 'Nerve and Sharp Tools Machine Any Stainless at High Speeds.' *Machinist*, 1952, vol. 96, Feb. 23, pp. 271-4.

A practical article, in popular terms, emphasizing the successful results which can be regularly obtained in machining stainless steels, provided that certain precautions are observed. Among the factors essential are strong and rigid tools, correct grinding of tools to produce a fine smooth finish on cutting edges, and the use of accurate measuring equipment and grinding jigs. It is urged that drilling of stainless steels should present no insuperable problem, provided that attention is paid to proper point angle, quality, and accuracy of grind, and generous use of coolant. The writer considers that, as a result of the advent of heavier and stronger machining equipment and carbide tools, the next few years will see the development of machining speeds hitherto believed to be impossible. As an example of what can be achieved in favourable conditions, an account is given of a typical test run used in producing a special bolt (of 416 or 303 stainless steel) in a ram-type turret lathe, and of experience in turning a valve fitting from 1$\frac{1}{2}$-in. stainless steel Type 316 down to 0·862 in. for 8 inches, in one pass, with a cut 0·319 in. deep. In conclusion, attention is drawn to the importance of properly ground, sharp tools, as a factor in prevention of undue work-hardening.

Resistance of Nickel-containing Materials to Alcohol

'Alcohol vs. Construction Materials.' *Chemical Engineering*, 1951, vol. 58, Nov., pp. 288, 290, 292-4, 296-8, 300-2, 304-5.

(Corrosion Forum summary, amplifying information given *ibid.*, Oct., 1948.)

The review is introduced by notes (by W. C. MOORE) on the non-corrosive character of alcohol and the way in which it may, due to contamination, become corrosive to metals and alloys. The nature of corrosion by ethyl alcohol is discussed, and it is pointed out that this problem is virtually one of corrosion by denaturants, which are about a hundred in number and vary widely in character. In this case also further complications are introduced by the presence of impurities.

The remainder of the review follows the lines usual in the Corrosion Forum series, discussing individually the following materials in relation to their suitability for use in contact with alcohol: Worthite, Hastelloy alloys, glass, protective coatings, high-silicon irons, Durimet 20, rubber, Chlorimet alloys, cements, iron and steel, nickel and nickel alloys, stainless steel, tantalum, carbon and graphite, aluminium, silicones, lead.

Worthite is stated to be very widely used for pumps handling alcoholic solutions. In the drug and pharmaceutical industries it is employed to ensure freedom of the product from contamination, and in solvent-extraction and other processes in which the alcoholic solutions are already contaminated with other substances, the corrosion-resisting material is needed to withstand attack. Typical examples are given of industrial processes employing Worthite pumps, e.g., in production of special lubricants, in petroleum refineries, for handling spray-cleaning liquids, and in production of adhesives. Reference is also made to uses of Worthite in plants manufacturing grain alcohol and allied products, and in distilleries.

Hastelloy Alloys. Hastelloys A, B, C and D are stated to be resistant to the common alcohols at all concentrations and temperatures. For example, Hastelloy D is widely used by producers of ethanol and iso-propanol, in the form of heating tubes for concentrating spent sulphuric acid, and Hastelloy B is used for pumps and piping handling alcohol-water mixtures in which the water phase contains process acids. Life of reaction columns for handling acidic water-alcohol mixtures has been lengthened by lining with Hastelloy C.

Durimet 20. This material is used in conditions for which the usual stainless steels are not adequate, due to heavy contamination of the solutions. Tests on Durimet 20 in methyl alcohol and ethyl alcohol at temperatures up to 200°F. (93°C.) indicate that it is virtually immune from attack. It has also shown a low rate of corrosion in a methyl alcohol-formaldehyde solution containing formic acid, and in a highly acidified butanol-water mixture containing 15 per cent. sodium chloride.

Chlorimet Alloys. Both Chlorimet 2 and Chlorimet 3 are immune from attack by the various alcohols, even at raised temperatures, e.g., up to 200°F. (93°C.). Since other, less expensive, materials are adequate for handling pure alcohol, the Chlorimet alloys are not normally employed for this purpose, but in the presence of certain contaminants their use is indicated. Reference is made to use of a Chlorimet 3 pump for re-circulating lauryl alcohol through a reactor into which chlorine is injected to produce chlorinated alcohol, at temperatures up to 235°F. (113°C.). Chlorimet 2 has found useful application in handling the resulting chlorinated alcohol, in cases where small amounts of hydrochloric acid are present. A further use of Chlorimet 3 is for pumps handling a mixture of 98 per cent. sulphuric acid and an alcohol, during a sulphonation process.

Nickel and Nickel Alloys. Nickel, Monel and Inconel are usually highly resistant to all the alcohols, even at elevated temperatures. Many of the applications of these materials are in preparation and handling of drugs, perfumes, surgical solutions, etc., where risk of metallic contamination must be excluded. Other uses are in plant employed for reactions of alcohols with other chemicals, such as esterifications, in which the corrosive may be an acid such as acetic or sulphuric. The applications of the high-nickel materials also include distilling and condensing equipment in the recovery of alcohols by distillation from or with other solvents, such as acetates and acetone, in solvent-recovery processes. Monel and nickel are used to a considerable extent in production of glycerine, in soap and fatty-acid plants. The Ni-Resist cast irons, with the exception of the stainless type containing nickel 29-32, per cent., with chromium and silicon, may be subject to superficial rusting in water solutions of the alcohols, but rates of corrosion of all the Ni-Resist irons are very low.

Stainless Steels. The stainless steels are widely used in applications involving contact with alcohol, both in the industrial and the fine-chemicals and beverage industries. They also have wide application in handling ethyl alcohol. Type 304 is the most commonly used, but in some cases pitting of this steel has been encountered at the air line in hot methyl alcohol, and for such use Type 316 (molybdenum-containing) is preferred. The straight-chromium steels also are suitable for some types of equipment used in production of ethyl alcohol. The stainless steels are used in production of absolute alcohol, except in cases where certain dehydrating agents, such as zinc chloride, are present.

Type 304 steel finds extensive application in the brewing and wine industries, but where sulphur dioxide is present in wines Type 316 gives better service. Stainless steel is not affected by whisky, but in some instances cloudiness has been observed in whisky stored in stainless-steel containers, probably due to a catalytic effect of the metal. The steels are therefore not recommended for this application.

Nickel-Chromium Corrosion-Resisting Steels in Ethylene Production Plant

'Improved Ethylene Production. Processes Available for Important Product.' *Chemical Age*, 1952, vol. 66, Mar. 22, pp. 443-5.

This article points out the importance of ethylene production, among the many rapidly developing petrochemical industries. The principal application is for

ethylene glycol, used as an antifreeze, and a large amount of ethylene is also used in production of synthetic ethanol. Other major outlets are for ethyl benzene (an intermediate in the production of styrene), and for various halogenated derivatives. Particular attention is called to the value of ethylene in production of ethylene plastic, which is made by high-pressure catalytic condensation. Methods of producing ethylene are reviewed, and reference is made to some of the plants in which large-scale manufacture is proceeding. Some of the reactions involved in production, concentration, and purification are discussed.

Inter alia, it is noted that one of the principal problems in design of pipe stills for operation at the high temperatures required for ethylene production is selection of steels for the cracking coils. From the point of view of high-temperature strength only, the 25-20 chromium-nickel steel is particularly satisfactory, but recent work by the Phillips Petroleum Company has shown that this steel is inferior to the 18-8 grade from the point of view of resistance to erosion by carbon particles formed in the process, indicating the desirability of using the lower-alloy steel in parts of the furnace where the cracking conditions are rather less drastic.

Hydrogen-Sulphide Corrosion-Cracking of Nickel Steel

L. W. VOLLMER: 'Hydrogen-Sulphide Corrosion-Cracking of Steel.' *Canad. Mining and Metallurgical Bull.*, 1952, No. 478, pp. 103-9 (*Trans. Canad. Inst. Mining and Metallurgy*, 1952, vol. 55, Feb., pp. 89-95).

During the past three years at least fifty strings of 9 per cent. nickel steel tubing have exhibited excellent resistance to corrosive conditions of varying severity typical of those obtaining in the sweet condensate wells in Mississippi, Louisiana, and Texas. This experience, and the characteristically outstanding performance record of other nickel-alloy steels in service involving contact with hydrogen sulphide, dictated selection of 9 per cent. nickel steel tubing for a second well drilled in the sour-condensate field of South Western Alberta. The damaging effect of the reservoir fluids of this area, on well equipment, had been previously demonstrated by rapid failure of the A.P.I. grade N-80 tubing, stainless-steel wire lines, and alloy-steel fishing tools.

Two unexpected failures occurred in the 9 per cent. nickel steel tubing in the second sour-condensate well, and the detailed examination of these failures forms the subject of the present paper. The results, which are presented and critically discussed in considerable detail, throw some light on the general behaviour of steels in hydrogen-sulphide environments, and in particular elucidate some aspects of corrosion in sour-condensate wells. The tests made included determination of susceptibility of the following materials to stress-corrosion cracking in contact with tap water saturated with hydrogen sulphide and carbon dioxide in atmospheric conditions:—9 per cent. nickel steel containing 0·30 per cent. titanium; 5 per cent. nickel steel, with or without 1 per cent. chromium or 0·25 per cent. molybdenum; 5 and 9 per cent. chromium steels containing small percentages of molybdenum; A.P.I. grade J-55 and N-80 steels; stainless 'W' (322) nickel-chromium steel; high-chromium stainless steels (Types 410 and 416); Monel; K Monel, and Inconel.

Although the investigation is not yet complete, results to date are considered to justify the following conclusions:—

(1) The failures of 9 per cent. nickel steel tubing in the sour-condensate well were initiated by stress-corrosion cracking.

(2) Susceptibility to failure in hydrogen-sulphide environments is not limited to this type of steel: there is evidence that most steels heat-treated to produce mechanical properties in or above a critical range represented approximately by Rockwell hardness C 24 to C 26 may be rendered susceptible to failure.

(3) Plastic deformation greatly increases susceptibility of steel to failure by stress-corrosion cracking, but it is not an essential condition if the film of corrosion products is ruptured or removed by some means and the hardness of the steel is in or above the critical range mentioned above.

(4) The mechanism of hydrogen-sulphide corrosion cracking of steel was not proved by the results obtained, but evidence was found that a metallographic structural phase as a network may be a sensitizing factor. Embrittlement of steel by exposure to hydrogen sulphide is not considered a primary cause of failure, but it may be an important contributory one.

(5) It is believed that it may be possible to reduce susceptibility to failure by compositional changes in the steel. The non-ferrous alloys tested showed on tendency to crack, even when both hardness and applied fibre stress were high.

Stainless-Clad Steels: Literature Review

H. THIELSCH: 'Stainless Clad Steels.' *Welding Jnl.*, 1952, vol. 31, Mar., Suppl. pp. 142-60.

A survey of the literature, supported by a *bibliography* of 81 references, and amplified by contribution of unpublished information from various sources.

The scope of the review, and the classification of the subject matter, are indicated below:—

Definition. Stainless-clad steel is defined as a composite steel assembly in which a stainless steel is joined to a mild or low-alloy steel in such a way that the stainless layer is continuously bonded over the entire contact area.

Methods of Manufacture. The essential features of the four main methods of production are described, with diagrams: (1) roll welding, (2) casting, (3) intermelting, and (4) arc and gas welding: reference is also made to the Colclad process, in which certain steps involved in other methods are combined. The problem of carbon diffusion is discussed, and methods which have been adopted to prevent it are described, e.g., the use of an interlay of nickel or other material between the backing and the cladding materials. The nature of the bond zones obtained by various processes, and in various forms of clad material, are illustrated.

Physical and Mechanical Properties and Specifications. The significance of expansion and thermal-

conductivity is briefly considered, as affecting the properties of the final clad products, and the mechanical testing of clad materials is reviewed, with notes on the requirements of A.S.T.M., A.S.M.E., and other specifications. Methods of tensile, impact, fatigue, and thermal-fatigue testing are described, and stresses arising in clad materials due to heating and cooling are considered, in relation to their influence on the behaviour of components made in clad steels.

Fabrication and Heat-Treatment. Recommended procedure is outlined, with a table showing annealing treatments suitable for stainless-clad steels of various types.

Welding. Although stainless-clad steels are usually weldable without undue difficulty, certain precautions must be observed. Positioning and fit-up, groove preparation, plate thickness, welding procedure, dilution, and selection of stainless electrodes are considered, and recommendations are made on welding conditions to be preferred for various types of clad material. Information is also given on flame-cutting of stainless-clad steels.

A brief review is made of some *failures* which have been observed in parts made from clad steels, with notes on their causes. The scope of *application* of stainless-clad steels and liners is briefly indicated.

Cathodic Protection of Nickel-containing Materials

T. P. MAY and H. A. HUMBLE: 'Effectiveness of Cathodic Currents in Reducing Crevice Corrosion and Pitting of Several Materials in Sea Water.'
Corrosion, 1952, vol. 8, Feb., pp. 50-6.

Certain metals and alloys, under given conditions of exposure, are susceptible to localized forms of corrosion commonly referred to as pitting and as crevice corrosion. When the local sites of attack are situated on boldly exposed surfaces, the corrosion is simple pitting: the term 'crevice corrosion' is applied if the attack on small areas is associated with crevices or recesses where small concentration cells may develop. Susceptibility to such forms of corrosion seriously restricts the applications for which certain materials can be used, and it was the aim of the research reported in this paper to determine the possibility of protecting such materials, by cathodic means, to an extent which would render their use practicable in large-scale installations. The investigation had particular reference to exposure in quiet sea water, which gives rise to crevice corrosion and pitting of chromium- and chromium-nickel stainless steels, and nickel. Monel, in these conditions, suffers only slight, shallow, pitting, but this deterioration, although not structurally serious, mars the appearance of the material.

The experiments reported were conducted in sea water at Kure Beach, N.C. Test specimens were coupled to magnesium anodes, with appropriate resistors in each circuit, to control the currents. Potential measurements were made in the course of two runs, of four and six months' duration, respectively. The results showed that cathodic current in quiet sea water reduces pitting and crevice corrosion on Types 410 and 430 stainless steel, but that the use of the method is impracticable for these steels because it causes severe blistering when the current is sufficient to eliminate the corrosion. This blistering is due to hydrogen, which is formed on the cathode surfaces by the current. Hydrogen is also generated on mild-steel surfaces, but does not ordinarily produce blistering. Cathodic current effectively reduced the two forms of corrosion on nickel, Monel, and Types 302 and 316 nickel-chromium stainless steels, without development of blisters, even at 30 ma. per sq. ft.

Ni-Resist in Caustic Manufacture

H. O. TEEPLE: 'How Austenitic Nickel Cast Iron can Serve as an Alternate for Caustic Manufacture.'* *Reprint from Chemical Engineering*, Dec., 1951. Issued by International Nickel Co., Inc., 1952; 1 p.

Current large-scale expansion of chlorine production in the U.S.A. involves, in most cases, the use of either diaphragm or mercury cells, with resultant production of about 1·1 tons of caustic for every ton of chlorine. It appears doubtful whether the chemical industry will be able readily to absorb the increased supply of caustic and it is therefore probable that purity and low production costs will become increasingly important considerations to manufacturers. Materials of construction will be a significant factor, both from the point of view of life and serviceability, and as a means of maintaining the desired level of purity in the caustic. The suitability of nickel for contact with caustic has been known for many years and nickel and nickel-clad steel have been much used in this connexion, but the current conservation programme requires that use of nickel be kept to a minimum.

Among the substitute materials best suited for this class of service are the Ni-Resist series, of which Type 3 has been found to give the best results. The compositions of this and other grades of Ni-Resist are given in the table below. Service in caustic production involves, in addition to corrosive attack, frequent drastic alternations of temperature, and here the low thermal coefficient of expansion of Type 3 Ni-Resist is a characteristic which is highly favourable. For caustic service in which pumps and valves of special strength and toughness are required Ductile (spheroidal-graphite) Type 3 Ni-Resist is recommended. This material shows corrosion-resistance

Composition of Ni-Resist Cast Irons

	Type 1	Type 2	Type 3
Total carbon, %	3·0 max.	3·0 max.	2·75 max.
Silicon, % ..	1·0-2·5	1·0-2·5	1·0-2·0
Manganese, % ..	1·0-1·5	0·8-1·5	0·4-0·8
Nickel, % ..	13·5-17·5	18·0-22·0	28·0-32·0
Copper, % ..	5·5-7·5	0·5 max.	0·5 max.
Chromium, % ..	1·75-2·5	1·75-2·0	2·5-3·5

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Corrosion Rate of Nickel and Ni-Resist in 50-65 per cent. NaOH (81 days, boiling)

	i.p.y.
Type 1 Ni-Resist (15% Nickel) ..	0·030
Type 2 Ni-Resist (20% Nickel) ..	0·0033
Type 3 Ni-Resist (30% Nickel) ..	0·0004
Nickel	0·0001
Cast Iron	0·086

similar to that of the regular Type 3, with the additional advantage of tensile strength of the order of 60,000-65,000 p.s.i. (27-29 tons per sq. in.) and an elongation of 10-20 per cent.

In some of the less exacting conditions of caustic production Types 1 and 2 Ni-Resist can be used, but they would not be expected to show useful resistance to corrosion in a concentration range of 50 to 73 per cent.: for such conditions Type 3 should be used. Some comparative data on nickel and the three Ni-Resists are given in the table above. The combination of mechanical and physical properties with its corrosion-resistant quality, makes Type 3 Ni-Resist an optimum material of construction for pumps, valves and cast metal parts in caustic service, during the period in which nickel is restricted. Ni-Resist of that composition may be regarded as a good alternative to nickel for alkali concentrations of 50 to 73 per cent. For handling caustic alkalis of higher than 73 per cent. concentration nickel is still the most economical material.

Corrosion Testing: Critical Review of Methods

F. L. LAQUE: 'Corrosion Testing.'* Reprint of Twenty-Fifth Edgar Marburg Lecture to the American Society for Testing Materials, June 1951; 89 pp.
Issued by International Nickel Co., Inc., 1952.

In this comprehensive review of corrosion-test methods the author has drawn on data from investigations which have been carried out under the aegis of the American Society for Testing Materials, on outstanding publications in the literature of corrosion, and on his own extensive experience in corrosion research over a long period. The survey comprises a description of the main features of tests which have been proposed for estimation of susceptibility of metallic materials to corrosion, a critical consideration of the advantages and limitations of the respective methods, and an evaluation of the extent to which the results of tests made by the various procedures can safely be used as a basis for forecasting the behaviour of materials in service. The review is illustrated by many figures and tables showing corrosion-testing equipment, the condition of corroded surfaces, and the results of accelerated and long-time corrosion tests made under atmospheric conditions and in liquid media. The *bibliography* contains 95 references.

Welding of High-Temperature Nickel-containing Materials for Gas-Turbine Components

J. L. SOLOMON: 'Welding of High Heat-Resistant Materials.' *Welding Jnl.*, 1952, vol. 31, Mar., pp. 233-8.

Design of a typical gas-turbine unit is illustrated, and a drawing of a combustion chamber is shown, as a background to an account of methods used in welding of the nickel-chromium (Nimonic) alloys, heat-resisting nickel-chromium steels, and titanium, used in various components. The information given is based on practice in the plant of Sciaky Brothers, Chicago. Particular attention is drawn to the advantages of using three-phase equipment for seam-welding of the high-temperature materials: the benefits to be derived from this procedure have been confirmed by tests made in a number of works in the U.S.A.

Flash-Butt Welding of High-Temperature Alloys

I. A. OEHLER: 'Flash-Butt Welding of High-Temperature Alloys.' *Welding Jnl.*, 1952, vol. 31, Mar., pp. 230-2.

Flash-butt welding, which is widely used for joining carbon and alloy constructional steels, may also be employed with advantage in welding heat-resisting alloys and steels. The major problem involved in applying the procedure to such materials is that of producing a sufficiently high and uniform temperature throughout the cross section of the joint and extending sufficiently far back towards the dies to permit adequate upset. The author of this note discusses some of the modifications of technique which are required for successful flash-butt welding of high-temperature materials, and makes recommendations with regard to specifications for equipment and procedure.

Welding of Austenitic to Ferritic Steels, Using Austenitic Electrodes

R. W. EMERSON and W. R. HUTCHINSON: 'Welded Joints between Dissimilar Metals in High-Temperature Service.' *Welding Jnl.*, 1952, vol. 31, Mar., Suppl. pp. 126-41.

A concise review is made of the history of metal-arc welding of dissimilar ferrous metals, with particular reference to the joining of chromium-molybdenum steels to austenitic types, for use in the petroleum and steam-engineering industries. At the time of inception of the research reported in this paper it was considered that two major problems existed: (1) effect of differential expansion between the austenitic and ferritic materials, and the possibility of fatiguing action at the austenite-ferrite interface resulting from cyclic temperature conditions, and (2) effect of diffusion, and carbon migration from the ferritic to the austenitic material, resulting from post-welding heat-treatment, service temperatures, or a combination of the two. In view of the work known to be already in hand on the first of these problems (subsequently reported in *Trans. Amer. Soc. Mech. Eng.*, 1949, vol. 71, pp. 643-64), the present authors concentrated research on the second aspect. Their report, contained in this paper, covers the effect of time and temperature on the structural stability of welded joints between austenitic and ferritic materials made with austenitic electrodes, with particular reference to carbon migration, depletion and recrystallization of the ferritic base metal at the austenitic weld-metal interface, and associated effects on the mechanical properties of such joints. The paper also records obser-

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vations made on the relative carbide-stabilizing effects of chromium, vanadium, and titanium when present in the ferritic base metal, and the effects of a vanadium-bearing weld deposit used as 'buttering' medium on carbon and chromium-molybdenum steels prior to welding with austenitic electrodes.

The ferritic steels used were chromium-molybdenum and plain-carbon types, and the austenitic plates were of Types 347 (niobium-stabilized 19-9), 316 (18-12-2 chromium-nickel-molybdenum), 309 (25-12 chromium-nickel) and 310 (25-20 chromium-nickel) grades. All were welded with $\frac{1}{8}$-in. and $\frac{5}{32}$-in. diameter reverse polarity d.c. lime-type electrodes: the core wires were of the four types of austenitic steel mentioned.

From the detailed and well illustrated account of the experiments made, the authors draw the following conclusions.

'Fractures occurred in slow-bend test specimens and impact-test specimens in the proximity of the 3 per cent. chrome-1 per cent. moly ferritic base metal-austenitic weld metal interface when tested after ageing for 5000 hours at elevated temperature. Under the same conditions, conventional tension tests did not fracture in this location, but in the ferritic base metal. The observed location of fracture is believed to have resulted essentially from the migration of carbon from the 3 per cent. chrome-1 per cent. moly base metal into the austenitic weld deposit.

'The average impact strength as determined by Charpy tests was found to be lower at the austenitic-ferritic interface of test plates given a 1550°F. (840°C.) post-weld heat treatment than in those given a 1350°-1375°F. (735°-745°C.) post-weld treatment, when tested after 5000 hours at simulated operating temperatures, thus emphasizing the desirability of maintaining a low stress-relieving temperature after welding.

'Metallographic observations quite consistently revealed the occurrence of exaggerated grain growth in the 3 per cent. chrome-1 per cent. moly base metal along the line of fusion in the specimens given the 1550°F. (840°C.) post-weld heat-treatment, whereas this was only occasionally observed in the specimens given the 1350°-1375°F. (735°-745°C.) post-weld heat-treatment, with the one exception of the specimens removed from the test plate welded with 347 electrodes and stress relieved at 1350°-1375°F.

'Contrasting the carbon migration in carbon steel versus 3 per cent. chromium-1 per cent. molybdenum steel after 5000 hours at elevated temperature, it is quite apparent that 3 per cent. of chromium has a considerable effect in stabilizing the carbides in the 3 per cent. chromium-1 per cent. molybdenum steel.

'Short time tests at elevated temperatures indicate both vanadium and titanium to have a beneficial effect on the carbide stability of low-alloy ferritic steel, the latter material being extremely effective.

'Although the presence of strong carbide stabilizing elements in ferritic steels is effective in preventing carbon migration from such a material into a high-chromium austenitic weld, care must be exercized to avoid the presence of such elements in excess of that required to stabilize the carbon, if such materials are to be welded with electrodes which will produce weld deposits of relatively lower carbide-stabilizing power.

'Carbon migration is not dependent upon the occurrence of exaggerated grain growth, but the rate of carbon diffusion appears to progress more rapidly in those instances where columnar grain growth was found.'

Facing of Metal-Shearing Blades with Hastelloy C

'Life of Shear Blades Increased Fourfold by Hard Facing.' *Nickel Topics*, 1952, vol. 5, No. 2, p. 5.

Blades of special tool steel, on shears cutting nickel and high-nickel alloys, normally give a service life up to 100,000 pounds of metal handled. Facing the blades with Hastelloy C has resulted in a 4-to-1 improvement. Some 400,000 pounds of high-alloy billet can now be sheared, after which the blades can be machined and re-faced several times before actual replacement of the shears is necessary. Some of these tools have now been in use for over three years. The Hastelloy C welding rod flows easily and is readily applied, without the necessity for pre-heating or peening.

Spraying of Metals: Properties of Sprayed Coatings

S. TOUR: 'Modern Developments in Metallizing.' *Welding Jnl.*, 1952, vol. 31, Mar., pp. 199-207.

A review of modern developments in equipment and technique, emphasizing the improved properties now obtainable in sprayed coatings, e.g., by sealing and impregnation, and the extended applications resulting from such advances in procedure. Recommendations on application of sprayed coatings, and data on their properties, include information on nickel-containing types. It is urged that metallization has an important future in prevention of corrosion: a comprehensive series of tests, designed to determine the atmospheric corrosion-resistance of a series of coatings, is being planned, under the sponsorship of the American Society for Testing Materials.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks.*

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